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FRAMING SUSTAINABILITY IN HUMAN-CENTERED PRODUCT DESIGN

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ABSTRACT

There is a global imperative for engineers to design sustainable products. However, user-centered designers have repeatedly found that sustainability is not necessarily a widespread user need. Based on user research from a graduate-level product design course, we present findings on how users define and describe sustainability, how sustainability issues interact with user needs, and the tradeoffs and feelings people have when faced with sustainability trade-offs. We also step through a case study of one design team's findings about sustainability, and how it affected the direction of their mission statement and product strategy. Based on these results, we propose a selection of recommendations for how to facilitate the design of innovative and sustainable consumer products.

KEYWORDS

Sustainable Design, Human-Centered Design, User Needs Research

INTRODUCTION

Human impact on the environment is an important societal issue that needs to be addressed by the engineers who build our material world. However, engineers are also subject to the business and market forces that dictate what is marketable and profitable. For this paper we define "sustainability" as "meet[ing] the needs of the present without compromising the ability of

future generations to meet their own needs" (United Nations, 1987). Sustainability is also often described as "the quality of a state or process that allows it to be maintained indefinitely; the principles of sustainability integrate three closely interlinked elements—the environment, the economy, and the social system—into a system that can be maintained in a healthy state indefinitely" (National Forestry Database Program, 2005). With the significantly increased attention to both environmental and social issues today, engineers are faced with having to achieve the goals of sustainability as they design new products

Previous years' experiences in teaching sustainable design to teams attempting to meet the three-part goal of sustainability (Agogino et al., 2008) have built upon the framework presented in Figure 1, based on the concept of sustainability as the intersection between the environment, the economy, and the social system (Elkington, J., 1994). The figure describes the various intersections between social, economic, and environmental goals as they relate to product design. A product that meets social and economic goals is *Human-Centered Design*, as it ensures market success by studying and addressing a customer need, but may not necessarily be an environmentally friendly product. A product that meets social and environmental goals but is not financially successful is an *Uneconomical Green Design*. These products may meet a user need with less environmental impact, however their lack of an appropriate financial model makes them an uneconomical choice and generally unsuccessful in the

marketplace. A product that meets environmental and economic goals, but fails to meet human-centered needs is an *Unadopted Green Technology*. While making financial and environmental sense, the failure to meet user needs results in the product failing by lack of use or in the marketplace, despite making economic and environmental sense. Ideally, engineers would aim for the shared space where environmental, economic, and social goals are all met in *Sustainable Design*.

Previous research found that customer interviews did not identify sustainability as a top need (Agogino et al., 2008). In spite of this, sustainable design is still an important aspect of companies' social responsibility goals. In addition, customer attitudes and opinions on sustainability still affect how sustainable designs are interpreted and adopted in the marketplace. It is therefore important for designers to understand their customers' attitudes about sustainability in order to gauge how the final concept can best match customer needs while also addressing the company or designer's values.

This paper explores the following research questions:

- What role does sustainability play in users' everyday lives? How does it impact their decisions concerning consumer products or services?
- How can designers address sustainability within the constraints of users' perceptions?

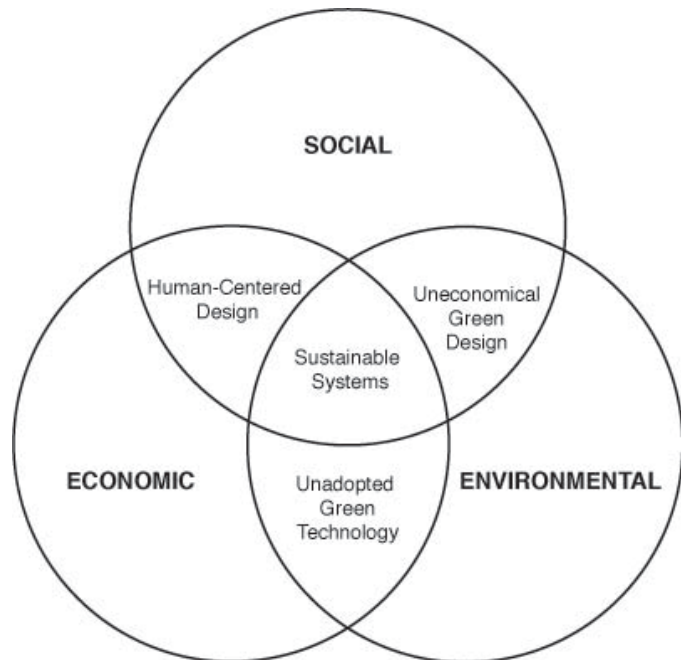


Figure 1: The Design of Sustainable Systems as the sum of the triple bottom line of Social, Economic, and Environmental goals.

RELATED WORK

Brezet (1997) describes four stages of sustainable design innovation: Product Improvement, Product Redesign, Function Innovation, and System Innovation. Most Design for Sustainability (DfS) literature focuses on Product Improvement, which is comprised of improving an existing product's environmental impact, often to meet regulatory compliance; or on Product Redesign (e.g., Bryant et al. 2004), where the concept remains the same but detail design is further developed or replaced by designs that improve the product sustainability throughout the product lifecycle. By including sustainability thinking earlier in the conceptual design process as part of strategic thinking, designers have the potential to achieve Functional Innovation, which involves changing the way functions are fulfilled, or System Innovation, the development of new products or services that require changes in organizations or infrastructure (Lofthouse 2003). However, our previous human-centered sustainable design courses have found that the designers, and not the users, set specifications for the sustainability of the product (Agogino et al. 2008). Therefore, human-centered designers may have to address sustainability as a separate priority from user needs.

Blevis' paper on Sustainable Interaction Design explores the impact sustainability considerations would have on individuals' interactions with technology and gives recommendations for DfS that are better suited for the conceptual design phase (2007). Primarily, he proposes the sustainable design principles of linking invention & disposal, and promoting renewal & reuse. He suggests that these primary principles can be achieved through three secondary principles: Promoting quality & equality, De-coupling ownership & identity, Using natural models & reflection.

Prior consumer behavior research has focused on the select market segment of people who do view sustainability as a user need. Webster (1975) used various metrics to quantify a general persona of the "Socially Conscious Consumer". Mayer (1976) went back to challenge a few of Webster's conclusions and further develop the persona of the Socially Conscious Consumer. Schlegelmilch et al. (1996) investigated whether or not socially conscious consumers' beliefs actually influenced their purchasing behavior. More recently, market researchers have focused on the Lifestyle of Health and Sustainability (LOHAS) segment, people who have a "profound sense of environmental and social responsibility", which make up 23% of U.S. consumers (French & Rogers, 2005). However, all of this research is clarifying the attitudes and behaviors of socially conscious consumers exclusively, and does not necessarily factor in to mainstream, everyday perceptions of socially conscious consumption.

Hanks et al. (2008) uncovered the attitudes towards sustainability and technology of “millennials”, or people between the ages of 18-21, via a survey distributed to undergraduate students. The framework used to understand this segment was “people who are concerned about sustainability” vs. “people who are apathetic about sustainability”, and “people who like new things, especially latest technology” vs. “people who like quality, enduring things – reuse, value, care and maintenance, value to others”. They developed specific profiles for combinations of these variables, based on their concerns: *individual material success*, *legacy material success*, *collective material success*, and *global collective fate*. Hanks et al. also propose design strategies for improving the sustainability attitudes of each profile. However, these strategies do not factor in how sustainability is interpreted by those who are “apathetic about sustainability”.

METHODOLOGY AND TESTBED

Our data are collected from the documents produced by student design teams in the Fall 2008 semester of ME 290P, “Managing the New Product Development Process: Design Theory and Methods”, a graduate-level multidisciplinary design course. This course did not necessarily focus specifically on the concept of “sustainable design”, although concepts that met the “triple bottom line” were presented as examples of “good design” for the class. In addition to a financial product analysis, there was also a required environmental analysis assignment.

At the beginning of the semester, thirteen teams were formed:

- Body Powder*
- Fast Food for Teens
- Home Cleaning with Children
- Custom Printing for Small Businesses
- Sustainable IT
- Sustainable Fabric for Interior Design
- Waste Free Refrigerator
- Hospital Urinal System Redesign *
- CookCare Rentals
- Solar Installation
- SeniorWeb Access for Seniors*
- Small Car Lifestyle
- Functional Chocolate for Millenials

Only three of these teams were student-initiated, marked with an asterisk. All other projects were from project proposals recruited from client companies. Many of these client companies emphasized sustainability as part of their corporate values. As a result, many teams addressed sustainability during their user research.

Each team was asked to submit summaries of their team’s insights from user research, as well as mission

statements from after the first iteration of user research. These mission statements and research summaries were analyzed for the teams’ emphasis on sustainability.

The thirteen projects had varying levels of emphasis on sustainability (Table 1). None of the student-initiated projects (Baby Powder, Hospital Urinal Redesign, Senior Web) had a sustainability emphasis. Four teams (Functional Chocolate, Fast Food for Teens, Custom Printing, Small Car Lifestyle) were sponsored by companies who valued sustainability; however sustainability was not necessarily a salient theme in the teams’ user research. Three teams (Home Cleaning, CookCare Retail, Waste Free Refrigerator) had a strong emphasis on sustainability in their mission. Finally, there were three teams (Sustainable IT, Sustainable Fabric, Solar Installation) in which sustainability was a primary area of focus. These teams were tasked with the promotion of sustainability information, values or technologies in their project. Therefore, they were forced to address sustainability issues with their users head-on.

All of the teams spoke with a wide range of users, including both sustainability novices and aficionados. The teams with a strong or focused sustainability emphasis sought out customers who had already acted on sustainability values (e.g. the LOHAS market segment). Generally, these teams addressed sustainability in their user interviews more than other teams; as a result we focused on the user research from these teams to uncover sustainability’s role in users’ lives and consumer decisions. For these teams, the user needs research summary was first analyzed and clustered into broader themes. Then, the available interview notes from these teams were analyzed for comments and quotation indicating trends within the overarching themes. Trends and themes in their responses are presented in the next section.

Table 1: Level of Sustainability Emphasis among NPD 2008 Groups

Minimal Sustainability Emphasis	Body Powder Hospital Urinal System Redesign SeniorWeb Access for Seniors
Modest Sustainability Emphasis	Functional Chocolate for Millenials Fast Food for Teens Custom Printing Small Car Lifestyle
Strong Sustainability Emphasis	Home Cleaning with Children CookCare Rentals Waste Free Refrigerator
Sustainability Focus	Sustainable IT Sustainable Fabric for Interior Design Solar Installation

RESULTS I: DEFINING SUSTAINABILITY

Many users recognized that sustainability could take on multiple meanings. Often users described sustainability as an abstract concept such as:

- “People, Profit, Planet”, a phrase often attributed to John Elkington and the *Shell Report* (REF, SustainAbility)
- “Equity, Economic, Environment (and Education)”
- “Live our lives such that future generations have a quality of life greater than or equal to ours”, similar to the definition found in the Bruntland Commission Report (United Nations, 1987)
- “Process that mimics a natural ecosystem”, a biomimetic definition (Benyus 2002)
- “Simplicity in life”
- “Do something good for mother nature”

Several of these sustainability definitions are similar, however these abstract definitions are more about values than functional needs.

What does Sustainability look like?

Most customer interviews conducted by our design teams described sustainability through examples of products or qualities that they considered “sustainable”. The users’ product descriptions generally included the following themes:

- **Efficient/Smart Use of Resources:** this is often related to efficient use of energy (e.g., “energy efficient home”, “low-energy appliances”). One interviewee mentioned “the smart use of resources during the manufacturing process”.
- **Reduce Waste:** Not creating excess waste during a product’s manufacture or use. Most customers are aware of this especially when considering the product’s packaging – excessive packaging is particularly wasteful. Many people also brought up recycling or composting as an alternative end-of-life for a product instead of a landfill.
- **Renewable Resources:** The product is made out of materials and “resources that do not have a finite supply”.
- **Long Product Lifetime:** Many people wanted products that would last a long time, or could be repaired. Reducing consumption by purchasing fewer, higher-quality products was seen as a path to a more sustainable lifestyle. Anti-consumerism as an approach to sustainability was noted by one user, “extreme sustainability is to not buy anything”.
- **Location, Location, Location:** Many users mentioned that it is important where something is made, for transportation, product quality, and social concerns. This was important in terms of both agricultural products and manufacturing locations.

Much of how users view the sustainability of a product consists of the use phase: How long do they use a product? Is it energy efficient during use? How much packaging does it come with? Is it made out of renewable resources? This use emphasis of sustainability is understandable because consumers have a limited or vague sense of how things are manufactured. As a result, a company conveying the value of green manufacturing may need to depend on the influence on the product’s market perception of trustworthy sustainability labeling or certification, or on education and marketing about the product’s origins.

RESULTS II: SUSTAINABILITY AND NEEDS

It was important for many of the teams to negotiate the relationship between user needs and sustainability values.

User Needs Can Align with Sustainability Values

Many of the teams who emphasized sustainability with user needs found that, although sustainability itself was not a top need, many of the users’ needs and values aligned with specific aspects of sustainability. These needs included:

- **Health and wellness.** Products that are good for the environment generally do not contain toxic or carcinogenic ingredients. For example, parents of small children care passionately about their children’s wellbeing and want to use products that will support a clean, safe, and non-toxic environment for their children. Also, some parents were drawn to more sustainable diapers, not because the lack of chlorine bleach was good for the environment, but because it meant their children did not suffer from diaper rash.
- **Efficient Performance.** Users value products that do their job efficiently. This is especially true when that product consumes a resource that the user has to regularly pay for, such as electricity, water, or gas, to do its job.
- **Preventing Waste.** Although the Waste Free Refrigerator team was initially instructed to design a “rotten food detector”, customer research revealed that users actually wanted to prevent food waste, and therefore prevent them from wasting their money on food that would go bad. Product or material waste often translates to the user wasting their money or time. Thus cost savings have been one of the major motivations for companies to adopt sustainability practices.
- **Product Quality.** High-quality products should last a long time without needing replacement. For example, Sustainable Fabrics appealed to customers looking for high-quality fabric, regardless of whether or not its sustainable manufacture was a draw.

- Meaning.** Meaningful products are more likely to have a longer product life, and more likely to benefit from additional information regarding the product's creation (Oehlberg et al., 2007). For example, one interviewee discussed using Sustainable Fabrics material for a kimono, and how the story of the fabric would be very important for this personal artifact. If it's already a meaningful artifact, additional meaning and therefore product value could be added to the object through the "sustainability story".

	Home Cleaning	CookCare	Waste Free Refrigerator	Sustainable IT	Sustainable Fabric	Solar Installation
Health and Wellness	○		○			
Efficient Performance		○	○	○		○
Prevents Waste		○	○			
Product Quality		○	○	○	○	○
Meaning	○	○		○	○	○

Table 2: Teams with strong or focused sustainability emphasis, and the presence of needs aligned with sustainability.

Top Needs Easily Trump Sustainability

When describing sustainable products, some customers noted that products cannot just be sustainable, they need to be functional; as one interviewee from the CookCare Rental research noted, "If it doesn't meet a user need, it's no good". Top needs that are crucial to the product's functionality and use absolutely cannot be compromised in deference to sustainability. For example, one interviewee from the CookCare Rental's research discussed rock climbing equipment: safety is so paramount in rock climbing equipment that customers are looking for the safest equipment, not the most green. In interviews with parents of small children, House Cleaning found that the children's safety was always most important, even though the environmental impact of the product would be a good additional feature.

RESULTS III: BARRIERS TO ADOPTION

Teams also looked at the factors that turned users away from choosing sustainability.

Planet vs. Price

There seemed to be an implicit assumption on the part of the interviewees that sustainability added to the price

of a product relative to its quality. They noted that economic constraints would keep people from opting for sustainable options. To these users, sustainability is not seen as a necessary function, but as an added value feature that costs extra.

Ironically, the abstract definitions of sustainability (including this paper's working definition of the "triple bottom line") generally include profitability and financial sustainability. It could be that many products that customers identify as "sustainable" may actually be uneconomical green design. Or, it could be that products' overt sustainability branding discouraged customers from considering it as a choice before price became an issue.

Many customers were not as concerned with whether or not a product was "cheap" or "inexpensive", but instead cared about product value: the performance and product lifetime being worth the price. While people will choose a sustainable product when performance and price are the same, sustainability becomes an economic tradeoff when more expensive than conventional products. Many users were willing to pay extra for a sustainable product, up to a limit.

Ultimately, for sustainable products to be successful in the marketplace, they must also be financially viable, as this is one of the three factors of sustainability. Solar Installation, for example, found that residential solar power needed to offer a financial benefit to its customers in order to be a realistic product.

Small Impact, Societal Guilt

Sustainable IT found that people recognize that their impact is small, and yet they experience societal guilt for sustainability. Sustainable IT also concluded that people do not feel guilty until specifically confronted or asked about sustainability. People have negative emotions when confronted with the societal problem of achieving sustainability. Not only do they bear the guilt of living in an unsustainable society, but they also feel powerless to change it. As a result, advertising sustainability may induce feelings of guilt or hopelessness instead of optimism for a more sustainable future. We will explore this in greater detail in the case study.

CASE STUDY: SUSTAINABLE IT

The Sustainable IT team had a strong sustainability emphasis: their project was to promote the client's more sustainable products among customers, therefore directly engaging customers with sustainability information.

As part of their mission statement, the team stated from the beginning:

	Before User Needs Research	After User Needs Research
Mission Statement	“To incentivize stakeholders to participate in sustainable IT using the client’s products & technologies”.	“To provide consumers with clear, accessible, actionable information about the sustainability value of personal computing products that makes them feel assured that their actions matter.”
Product Description	Our product will be a strategy for approaching Sustainable IT by focusing on: 1) consumer behavior 2) IT marketplace 3) method of comparison/measure ment 4) community	Our product will be a service that offers information about the sustainability value of different personal computing products and collects information about the users’ feedback for them to know the impact of their actions.

Table 3: Sustainable IT’s Mission Statement and Product Description, before and after conducting user needs research

We define Sustainable IT as the optimization of a product through its lifecycle: extraction, manufacture, use, waste mitigation and reclamation – utilizing this cradle-to-cradle framework to calculate and optimize the total cost of ownership using “Joules” as the currency.

We believe that certain elements of sustainability - energy usage & maintenance, and recycling/re-use - are tangible and facilitate the direct participation of the consumer. Therefore we intend to focus on those two elements for our product analysis.

The Sustainable IT team interviewed 14 people, ranging in age from 24 to 65; 11 were from California. Detailed notes were available for 9 of the interviews.

In their user research plan, the team stated their effort to interview users that represent a range of:

- Level of Passion for Sustainability (Passionate vs. Indifferent)
- Adoption of Technology (Early, Mainstream, Late)
- Socio/Economic (Price-Sensitive vs. Indifferent)

The questions asked in their user interviews included:

- What do you think about sustainability? How do you describe it?
- What are the most pressing sustainability concerns in your personal life?
- What are the most pressing sustainability concerns to our world and society?
- In what ways do you try to be sustainable?
- In what ways do you think you are not sustainable? What keeps you away from it? What keeps you from living a more sustainable lifestyle?

Defining Sustainability

Of the nine detailed interviews, only five people defined sustainability in abstract terms. Two people described sustainability as an “ecosystem,” two people mentioned the concept of long-term survival for either a business or future generations. One person described green as “zero impact. Sustainable is no negative impact or an acceptable impact”.

Of the nine detailed interviews, six people included concrete features in their definitions of sustainability. One mentioned product lifetime as being an issue. The remaining definitions were mostly concerned with the smart use of resources (2 people), and the ability to renew resources that are being used (3 people).

Sustainability and User Needs

The Sustainable IT team did not necessarily begin with a user need to focus on – instead, they started from their client’s point of view that sustainability *should* factor into their customer’s purchasing decisions, and approached it as an education issue. The Sustainable IT team identified four specific user needs for making purchasing decisions based on sustainability:

- Clear Information
- Understanding of Definitions & Lifecycle
- Clear Value & Benefit
- Relevance to Personal Experiences

Barriers to Adoption

For the Sustainable IT group, addressing barriers to adoption of sustainable technology was the main focus of the project itself. As a result, the summary of their user needs research included implications relating to both the economic and guilt barriers to adoption:

Economic

- Economic problems keep many people from being sustainable
- Sustainability seems expensive
- Key factors in purchasing decisions are convenience, cost efficiency, value

Guilt

- People experience societal guilt
- People do not feel guilty until specifically confronted or asked about sustainability
- People recognize that their individual impact on environmental sustainability is small

Perhaps the implication from the summary that best captured both the economic and guilt barriers is: “People want both the economic benefit, and the pat on the back”. This statement of a desired positive experience, in addition to the four identified needs, guided the team

to revise their mission statement from its previous version (see Table 3) to be:

“To provide consumers with clear, accessible, actionable information about the sustainability value of personal computing products that makes them feel assured that their actions matter.”

This revised statement reflects that instead of simply “providing incentives”, the Sustainable IT team realized that it was more important to their goals to help users make the right decision by both informing customers that sustainability did matter in their IT purchasing decisions, providing customers with the information they needed to make the right choice, and rewarding customers for making sustainable decisions.

RECOMMENDATIONS

The following are recommendations for teaching sustainability with design, so as to best prepare engineers for the “real world” sustainability challenges that are present in the consumer market.

Acknowledge up front that sustainability may not be expressed as a priority during interviews or focus groups on customer and user needs. While market data over time shows a trend of increasing interest in sustainability, sustainability is far from widespread in the consumer population. The diffusion of innovation literature suggests that there will be early adopters as well as a large population of laggards for the adoption of any new technology or trend. Design teams thus should be encouraged to frame their projects in terms of whether or not it will be necessary to educate consumers about sustainability.

Help design teams distinguish customers’ abstract understanding of sustainability from concrete requirements that may lead to sustainable product features. This will enable students to differentiate between their own concepts’ ability to communicate sustainability both through concrete features (e.g., materials choice) as well as through more intangible aspects of the design including the advertising, packaging, or expected user experience. This experiential side of design will contribute the aesthetics, social meaning, and cultural meaning behind the product that speak to the user’s abstract understanding of sustainability.

Encourage design teams to identify and exploit opportunities where the needs users express, outside the context of sustainability, can be aligned with sustainability goals. When design teams are struggling to figure out how to bring a sustainability agenda to the market, it will help them to find ways in which they can help consumers achieve their own goals in parallel with becoming more sustainable.

Encourage students to use creativity to overcome seemingly unbreakable conflicts between economical and environmental goals. Creative solutions often arise from seemingly unbreakable conflicts. In the case of sustainability, there appears to be a perceived conflict between sustainability and cost. These tensions have the potential to provide a ripe source for creativity and innovation for the teams. (WalMart’s attempts to implement sustainability throughout its supply chain, for example, shows that such conflicting objectives can be overcome.)

Keep design teams focused on delivering products that not only meet use and usability needs, but also meaning-based needs. (Barry and Beckman) For teams that prioritize sustainability, designers should not necessarily assume that users prioritize sustainability to the same extent as the team. Different perceptions of sustainability also exist among different user groups. Just as with user needs, the team needs to align the team’s frame with the user’s frame when it comes to sustainability (Hey et al., 2007).

Facilitate cross-project learning about the differences in how sustainability is framed in different project settings. While this paper has brought together many of the insights reached when the teams informally shared their findings on sustainability with each other. Teams with a strong sustainability emphasis were able to learn a lot from teams whose projects’ main focus was sustainability. By letting students learn from each others’ projects, they can find out about the range of possible situations they will confront in industry.

FUTURE WORK

The major lessons learned from this meta-analysis of user needs studies from design teams in a semester-long course in new product development is that:

- There are still customers who don’t rank sustainability very high in their purchase criteria for product or services.
- This leads to conflict on New Product Development teams that want to design something sustainable.

As a result of our experience with design teams struggling with different levels of this concern, we have proposed recommendations to other faculty teaching similar classes that address both human-centered design and sustainability topics.

Although our data set was based on user studies from a multidisciplinary graduate design class, understanding how any new agenda – in this case sustainability – can be integrated into the New Product Development process is of value to practitioners in industry,

particularly when that process is being taught as customer-focused. Along those lines, we believe future work can:

- Build on existing literature in marketing and innovation (e.g., on diffusion of innovations) to better understand adoption of new designs/technologies.
- Integrate that understanding with the customer-focused design literature.
- Find new tools and techniques that would allow teams to better integrate the two.

In general, future work must include exploring the area of persuasive sustainable design – the potential for design to not only meet user needs, but also play a persuasive role in shifting users to a more sustainable mindset. Persuasive sustainable design will require not only an understanding of user needs, but also understanding of sustainability perceptions and interpretations to best understand how to communicate the designers' values while still creating products that have commercial appeal.

Another issue to be addressed is how sustainability can and should be internally communicated with a design team. Sustainability and other internal design values are addressed within a team and then factored into a user-centered design process should also be a topic of study. We hope to develop a theory and methods on how designers can create products that meet user needs while simultaneously meeting internal designer values.

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